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American National Standard N538;

Classification of Industrial Ionizing Radiation Gauging Devices



AMERICAN NATIONAL STANDARD N538-1979

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American National Standards Institute
Subcommittee N43-3.2

Under the sponsorship of the
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Washington, D.C. 20234

Approved February 9, 1979
American National Standards Institute
New York, N.Y. 10018

ANSI N538-1979



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Foreword

(This foreword is not a part of American National Standard N538, Classification of Industrial Ionizing Radiation Gauging Devices.)

In 1972, the U.S. Atomic Energy Commission identified a number of areas in the regulatory process for which nuclear standards were desired. An appeal was made to the Priorities Committee of the ANSI Nuclear Technical Advisory Board for support and Subcommittee N43-3.2 was activated to develop this standard for gauging devices. Work on the standard was begun in 1973, and the draft proposal was completed in 1976.

This standard establishes a system for classification of gauging devices, which use sealed radioisotope or x-ray tube sources, based on performance specifications relating to radiation safety. In addition to specific tests for both use conditions and accident conditions, guidelines for other safety features and considerations are presented. This standard does not apply to the measurement performance of gauging devices.

Suggestions for improvement of this standard will be welcome. They should be sent to the American National Standards Institute, 1430 Broadway, New York, N.Y. 10018.

American National Standards Committee N43, on Equipment for Non-Medical Radiation Applications, which processed and approved this standard, had the following personnel at the time of approval:

Elmer H. Eisenhower, *Chairman*
(National Bureau of Standards)

<i>Organization Represented</i>	<i>Name of Representative</i>
Air Transport Association	Warren J. Weldon
American Chemical Society	Edward E. Beauchamp
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Abstract

This American National Standard applies to the radiation safety aspects of gauging devices, commonly called gauges, which use sealed radioactive sources or x-ray tubes for the determination or control of thickness, density level, interface location, or qualitative or quantitative chemical composition. This standard establishes a system for classification of gauging devices based on performance specifications relating to radiation safety. In addition to specific tests for both use conditions and accident conditions, guidelines for other safety features and considerations are presented. This standard does not apply to the measurement performance of gauging devices.

Key words: Device safety performance classification; gauges; gauging devices; ionizing radiation; radiation measurements; radiation safety; standard.

American National Standard

Classification of Industrial Ionizing Radiation Gauging Devices

1. Scope

This standard applies to the radiation safety aspects of gauging devices, commonly called gauges, which use sealed radioactive sources or x-ray tubes for the determination or control of thickness, density, level, interface location, or qualitative or quantitative chemical composition. This standard does not apply to the measurement performance of gauging devices.

2. Definition of Terms

Accessible Surface. Any surface of the gauge that can readily be reached by any part of the human body without the use of tools or without the removal of any part of the gauge.

Dose Rate (7 mg/cm²). For x-ray, gamma, and charged particle radiation, the radiation level in mrem/hour measured with a detector having a total window and absorber thickness no greater than 7 mg/cm² of tissue equivalent material.

Dose Rate (300 mg/cm²). For x-ray, gamma, and charged particle radiation, the radiation level in mrem/hour measured with a detector having a total window and absorber thickness no greater than 300 mg/cm² of tissue equivalent material. All neutron radiation levels in mrem/h are also included.

Dummy Source. Facsimile of a sealed source of exactly the same material and construction as a sealed source but containing, in place of the radioactive material, a substance resembling it as closely as practicable in physical and chemical properties.

Gauging Device (Gauge). A mechanism designed and manufactured for the purpose of determining or controlling thickness, density,

level, interface location, or qualitative or quantitative chemical composition. It may include components such as radiation shields and useful beam controls incorporated into the gauge in order to meet the requirements or specifications of this standard.

Isodistance Contour. The imaginary surface around a gauge at a specified distance from the nearest accessible surfaces. For practical reasons in this standard, the literal interpretation has been simplified as defined in section 7.3.2 and figures I and II.

Leakage Radiation. All radiation coming from within the source housing, except the useful beam.

Nearest Accessible Surface. The accessible surface(s) of the gauge closest to the point or region of interest.

Protective Barrier. A structure or obstacle to limit access of personnel to fields of radiation. A protective barrier is distinguished from a radiation shield in that it limits personnel access to radiation sources, whereas a radiation shield reduces radiation intensity.

Radiation Shield. The material used intentionally to reduce the intensity of radiation entering a region.

Radioactive Source. Any quantity of radioactive material which is intended for use as a source of ionizing radiation.

Scattered Radiation. Radiation that, during passage through matter, has been deviated in direction. (It may also have been modified by a decrease in energy.)

Source Holder. A device used to support and retain the source.

Source Housing. An enclosure containing or incorporating the source, source holder, and means for attenuation of the radiation.

Stray Radiation. The sum of leakage and scattered radiation.

Useful Beam. Radiation which passes through the window, aperture, cone or other collimating device of the source housing; sometimes called "primary beam."

Useful Beam Controls. The device(s) that affects the quantity, quality, and direction of the useful radiation beam which is emitted from the source.

X-ray Tube Source. A gauge radiation source producing penetrating electromagnetic radiation having wavelengths shorter than those of ultraviolet light. X-rays can be produced by bombarding a metallic target with fast electrons in a high vacuum, fluorescent techniques, or other means.

3.2 Source Access. The gauge shall be designed to restrict access to the source by unauthorized personnel.

3.3 Integral Radiation Shields. Shielding which is part of the gauge shall reduce the radiation emitted by the source to the levels required by the device classification.

3.4 Useful Beam Controls. A useful beam control system shall be provided in gauges whenever the useful beam is accessible and the radiation levels exceed 100 mrem/h at 5 cm from any accessible surface or 5 mrem/h at 30 cm. The useful beam controls may include (but not be limited to) the following radiation interrupting means:

- (a) Moving Shutter
- (b) Moving Source
- (c) High Voltage Power Supply Control
(in the case of x-ray tube sources.)

The prototype useful beam control system shall be tested through a sufficient number of cycles to verify the long-term reliability of the design.

3.4.1 Manual Useful Beam Control Systems. Manual useful beam controls shall be designed so that when the source is in the OFF condition, the measured radiation levels in the useful beam space shall be no greater than a dose rate of 5 mrem/h at 30 cm and 100 mrem/h at 5 cm (or the device stray radiation classification levels of section 6.1, whichever is greater) as measured in accordance with the procedures of section 7.3.

In the case of a gauging device with a measuring gap not exceeding 10 cm, the radiation level requirements of this section may be met by means of the useful beam control system alone or by means of an external shield in addition to the useful beam control system. The external shield, which shall be designed for easy and secure installation on the device, shall be supplied by the manufacturer. Means shall be provided for storing the external shield on the gauging device when it is not in use as a shield.

The source housing shall be constructed in such a manner that the source can be retained in the use positions and the full OFF position. A locking mechanism shall be provided to

3. Safety Features and Requirements

3.1 Source Integrity

3.1.1 Radioactive Source. The radioactive material shall be in the form of a sealed source which shall be classified in accordance with the American National Standard N542-1977, "Sealed Radioactive Sources, Classification."

3.1.2 X-ray Tube Source. The source shall be such that no radiation is emitted except by application of an electric current through an x-ray tube. Provisions shall be made to limit both the current through the tube and the voltage across the tube, so that radiation levels do not exceed the device classification under use conditions or through circuit component failures.

In the event of fire or abnormal elevated temperatures, provisions shall be made to insure the high voltage is automatically disabled before loss of any integral shielding. This provision exempts x-ray tube sources from accident condition classification.

physically secure the source in the full OFF position. This locking mechanism shall be operated only when the source is in the OFF condition.

3.4.2 Powered Useful Beam Control Systems.

A powered (non-manual) useful beam control system shall be designed such that if power fails the source will remain in, or return to, the OFF condition. With the source in the OFF condition, the measured radiation levels, in the useful beam space, shall be no greater than a dose rate of 5 mrem/h at 30 cm and 100 mrem/h at 5 cm (or the device stray radiation classification levels of section 6.1, whichever is greater) as measured in accordance with the procedures in section 7.3.

In the case of a gauging device with a measuring gap not exceeding 10 cm, the radiation level requirements of this section may be met by means of the useful beam control system alone or by means of an external shield in addition to the useful beam control system. The external shield, which shall be designed for easy and secure installation on the device, shall be supplied by the manufacturer. Means shall be provided for storing the external shield on the gauging device when it is not in use as a shield.

3.5 ON-OFF Indicators. Conspicuously visible signals, which positively indicate when the useful beam control system is in the ON condition, and when it is in the OFF condition, shall be located on or adjacent to the radiation source housing. The signals may be electrical, mechanical, or electromechanical and shall include legible signs describing their meanings. Additionally, for radiation fields greater than 2 mrem/h at 50 cm from the gauge or other surfaces, ON-OFF indicators shall be located so that no one can enter the radiation field associated with the gauge without being able to see the indicators, or appropriate signs shall be posted warning individuals to check the condition of the ON-OFF indicators.

3.5.1 Indicators for Manual Useful Beam Controls. Each gauging system having a manually operated useful beam control shall have a conspicuously visible signal to indicate when the beam control is in the full ON condition and when it is in the full OFF condition. Mechanical

indicators shall be directly coupled to the moveable beam control part.

3.5.2 Indicators for Automatic Beam Controls. Each indicating system shall consist of at least one ON indicating signal and one OFF indicating signal. If lights are used, a green signal indicates the OFF condition. The red signal indicates any other condition of the useful beam control. Administrative controls shall be established to maintain the proper operation of the ON-OFF signals (i.e., lamp bulbs which fail shall be replaced immediately).

3.5.3 Indicators for X-ray Tube Source High Voltage Control. A yellow or amber warning light with the notation "HIGH VOLTAGE ON" shall be located on the control panel and on, or adjacent to, the source housing and shall light only when power is applied to the x-ray tube high voltage circuit. Administrative controls shall be established to maintain the proper operation of the HIGH VOLTAGE ON signals. If the high voltage power supply control is the sole useful beam control, the indicator requirements of section 3.5 and 3.5.2 are substituted for this section.

3.6 Interlocks. Under normal conditions of use, there shall be interlocks or barricades to prohibit a person from encountering dose rates to a major portion of the body greater than 100 mrem/h. For conditions of infrequent use, or where such interlocks or barricades are physically impossible or impractical, appropriate instructions, auxiliary shielding, or administrative controls may be substituted.

On x-ray gauges, interlocks shall be incorporated (e.g., access covers, etc.) to prevent accidental exposure to the x-rays as well as the high voltages associated with the x-ray tube.

3.7 Labels

3.7.1 Identification. The gauge shall be durably and conspicuously marked, by a label(s) permanently affixed to the gauge, with the ANSI gauge classification, name of the manufacturer or vendor, and gauge model number.

3.7.2 Radiation Safety. Radiation safety labels shall provide instructions and precautions for safe operation of the gauge, except that

where such labeling is not practical because of space limitations documents such as operating and service manuals may be used to provide this information. For a gauge which employs a radioactive source, there shall be a durable permanent label indicating the type and amount of radioactive material, the measurement date, the standard radiation symbol, and a caution notice which shall read as follows or similarly:

“CAUTION-RADIOACTIVE MATERIAL”
or
“DANGER-RADIOACTIVE MATERIAL”

For a gauge which employs an x-ray tube source, there shall be a durable permanent label indicating the maximum operating current, voltage, and kVA, the standard radiation symbol, and a caution notice which shall read as follows or similarly:

“CAUTION-RADIATION; THIS EQUIPMENT
PRODUCES RADIATION WHEN
ENERGIZED”

In addition, a label which reads, “CAUTION-RADIATION; THIS EQUIPMENT PRODUCES RADIATION WHEN ENERGIZED” shall be located near or adjacent to each switch that controls the production of x-rays.

3.8 Instructions. Instructions shall be provided for the gauge regarding installation, operation, servicing and maintenance, and removal from installation. Particular attention shall be given to providing radiation protection instructions. Activities which should only be performed by a properly authorized person who is trained in radiation protection should be clearly identified. The user should be alerted to become knowledgeable in applicable state and federal regulations.

4. Conditions of Use

4.1 Auxiliary Shielding Barriers. Because of the occasional necessity to locate gauging devices in occupied areas, it may be necessary, for

purposes of radiation protection, to install auxiliary shielding or barriers around the source housing or gauging system. Any such auxiliary shield or barrier should be permanently installed and of rugged construction. Under normal conditions of use, the shield or barrier should reduce the stray radiation in occupied areas to levels consistent with good radiation protection practice or restrict access to excessive levels of radiation exposure. Temporary shielding or barriers may be necessary during servicing or maintenance of the gauging device or nearby equipment. A useful reference for auxiliary shielding and barriers is American National Standard N543-1974 (NBS Handbook 114).

4.2 Serviceability/Maintainability. The radiation source, its containment, and shielding shall be serviced and maintained only by individuals who are properly trained. This may require specific authorization by a regulatory agency. The gauging device shall be designed and installed so that it is possible to perform field service and maintenance without exceeding applicable radiation dose limits, provided the manufacturer’s instructions are followed.

4.3 Administrative Controls. In addition to any physical radiation protection safeguards provided by the gauging system manufacturer, the users of the gauging device should develop a radiation control program to adequately assure the safety of persons operating, maintaining, or working in the vicinity of the gauging device. The extent of the program is dependent on the hazard associated with the equipment involved. The elements of a program generally consist of appropriate safety practices, assignment of responsibility, and the maintenance of records and documentation.

Management for the user’s facility has the responsibility to review the circumstances under which the devices will be used and to decide on the extent of the radiation control program. A person knowledgeable in industrial gauge radiation safety practices may be consulted during this decision making process. Consultation is usually available from the manufacturer.

Administrative controls that should be considered are as follows:

- (a) Posting of safety notices to employees and various warning signs when required or desired.
- (b) Instructions to operators and persons maintaining the gauging devices.
- (c) Records retention:
 - (1) Documentation of receipt of the device.
 - (2) Location of gauge in the user's facility and initial radiological survey results.
 - (3) Leak tests and shutter operation test results when required.
 - (4) Personnel monitoring results.
 - (5) Documentation of disposal of the device.
- (d) Availability of a radiation protection specialist either employed by the user or available on contract, whose function would be to:
 - (1) Design and implement a radiation protection program to reduce and maintain personnel exposures to a level as low as is reasonably achievable.
 - (2) Provide for training of personnel where applicable.
 - (3) Consider personnel monitoring needs.
 - (4) Provide internal audits to review the overall radiation protection program.

Administrative controls such as special instructions, operating limitations, warning signs or signals, or other controls may be substituted for physical safeguards when the physical safeguards are not feasible. Any administrative control established under these conditions should insure that persons working around the gauging system will be prevented from receiving an annual cumulative whole body dose greater than 500 mrem.

4.4 Licensing and Registration. Federal and state regulatory requirements should be reviewed prior to obtaining the gauging device. A convenient source of information may be the manufacturer or distributor of the device.

5. Shipping

5.1 Packaging and Transportation. The packaging and transportation of radiation gauging devices shall comply with the applicable requirements of the pertinent regulatory or controlling authorities. Each shipper should establish procedures for determining that each package submitted to a carrier for transport has been correctly packaged and labeled in accordance with the appropriate regulations. Consultation is usually available from regulatory or controlling authorities or the gauge manufacturers. Prior to delivery of a package to a carrier for transport, the shipper shall assure that any special instructions needed to safely open the package have been sent or otherwise made available to the recipient.

5.2 Temporary Shielding. Each gauging device shall be provided with a shutter restraint or temporary shielding that will assure that the radiation field does not exceed applicable limits during shipping and storage. The shielding or shutter restraint shall be firmly fixed to withstand the normal conditions of handling and shipping. Gauging devices which employ an x-ray tube source are excluded from the requirements of this section, provided that capacitor discharge type gauges have the capacitor banks discharged so there can be no emission of x-rays. Adequate discharge of the capacitors shall be verified by using a suitable radiation monitoring instrument to show that no radiation is present.

6. Device Safety Performance Classification

6.1 Device Classification. Table I is a listing of test conditions and measurements to which a device may be subjected. The tests are arranged in order of increasing severity. The classification of each device type shall be determined by prototype testing for each test in the table or by calculations based on previous tests and physical characteristics data which demonstrate that, if the test were performed, the device would pass the test.

This standard applies only to safety considerations and does not imply that the gauge will operate as a measurement system during or after the tests. The order of testing is important only in that the stray radiation class must be determined first.

Compliance with the "accident condition" tests shall be determined by the ability of the gauge to maintain reasonable radiological safety. However, the safety features do not need to be operational or perform in accordance with their original intended functions. The necessary criteria for passing each accident test are that there shall be no dispersal of radioactive material and the source capsule shall remain captive in a protective source housing. Dummy sources may be used in these evaluations.

It should be noted that the maximum stray radiation dose rates in table I are determined at distances measured from the nearest accessible surface of the device. Since the dimensions of devices vary considerably, there is no specific relationship within a given classification between the dose rates at 5 cm, 30 cm, and 100 cm that will hold for all devices (i.e., the inverse square law does not apply).

Use of the ANSI classification for a gauging device signifies that not only have the conditions of table I been met, but also that the guidelines for the other safety features of this standard have been followed. Some of these can be complied with only after the system is installed in the user's facility (such as interlocks, remote indicators, and signs). Accomplishment of full satisfaction may require the combined efforts of the manufacturer, the installer, and the user.

6.1.1 Classification Designation. The classification of a gauging device shall be designated by the code ANSI followed by groups of digits that identify the tests which the gauge has met and a letter which designates a radioactive or x-ray tube source. Classification of temperature performance and accident conditions is not dependent on the source ON or source OFF condition. However, classification of the stray radiation performance is dependent on the source ON or OFF condition. This standard recognizes this difference and assigns a separate set of digits for the source ON and

OFF conditions for the stray radiation classification. This standard also recognizes the difference between radioactive and x-ray tube sources. Thus the fire test is not required for x-ray tube sources, provided the conditions of 3.1.2 are met.

The gauge classification shall be described using the following format after the code name ANSI:

A set of two digits which identifies the performance for temperature—first digit high temperature; second digit low temperature.

Followed by a dash and

A set of three digits which identifies the performance for stray radiation in the source ON condition—first digit for 5 cm, second digit for 30 cm, third digit for 100 cm.

Followed by a dash and

A set of three digits which identifies the performance for stray radiation in the source OFF condition—first digit for 5 cm, second digit for 30 cm, third digit for 100 cm.

Followed by a dash and

The letter R for radioactive source or the letter X for x-ray tube source.

Followed by

A digit which identifies the performance for the fire accident condition, except that this digit is generally omitted for an x-ray tube source.

TABLE I. Classification of Device Safety Performance Standards.

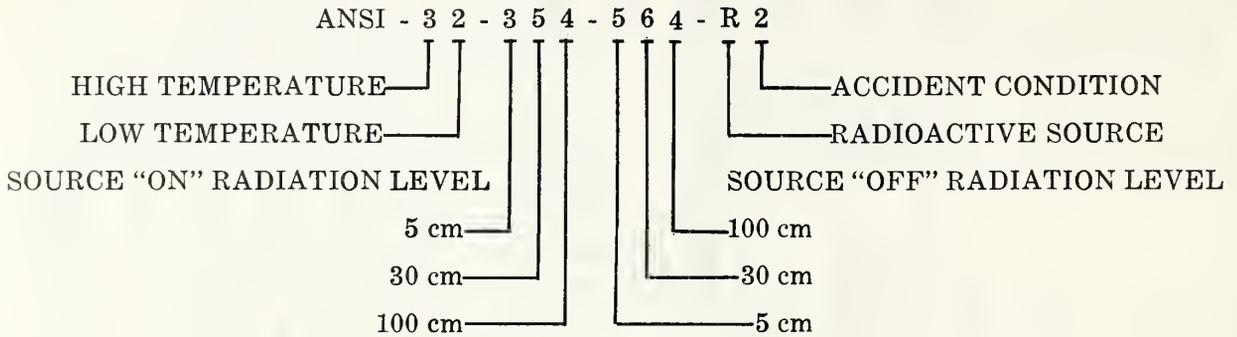
TEST/CLASS	1	2	3	4	5	6	7	8	9	S
USE CONDITIONS										
High Temperature	No Test	50°C (122°F)	60°C (140°F)	85°C (185°F)	105°C (221°F)	200°C (392°F)	300°C (572°F)	400°C (752°F)	600°C (1112°F)	Special
Low Temperature	No Test	20°C (68°F)	0°C (32°F)	-40°C (-40°F)	-79°C (-110°F)	-100°C (-148°F)	-196°C (-320°F)			Special
Stray Radiation at 5 cm ^{1,2}	No Test	200 mrem/h	100 mrem/h	50 mrem/h	20 mrem/h	5 mrem/h	2 mrem/h	0.75 mrem/h	0.5 mrem/h	Special
Stray Radiation at 30 cm ¹	No Test	100 mrem/h	50 mrem/h	20 mrem/h	5 mrem/h	2 mrem/h	0.75 mrem/h	0.25 mrem/h		Special
Stray Radiation at 100 cm ¹	No Test	10 mrem/h	2 mrem/h	0.75 mrem/h	0.25 mrem/h					Special
ACCIDENT CONDITION										
Fire ³	No Test	5 min. 538°C (1000°F)	20 min. 800°C (1475°F)	1 h 927°C (1700°F)	2 h 1010°C (1850°F)	4 h 1093°C (2000°F)				

¹ Distance measured from the nearest accessible surface of the device or as specified in section 7.3.2 and figures I and II.

² Due to the large dimensions of neutron detectors, it is impractical to make measurements at 5 cm from the surface of a gauging device containing a neutron source and hence Class 1 will be specified.

³ Standard U.L. Fire rating (time temperature curve). This test does not apply to x-ray tube sources (provided the conditions of section 3.1.2 are met).

Example: A typical beta radiation transmission gauge used to measure the thickness of a plastic film might be classified:



6.2 Other Conditions

6.2.1 Other potential use and accident conditions which might need further consideration but do not lend themselves to a rigid classification scheme include:

- (a) Corrosion
- (b) Vibration
- (c) Impact
- (d) Puncture
- (e) Compressive Loads
- (f) Explosion
- (g) Flooding
- (h) Distance to Work Stations
- (i) Personnel Occupancy Times
- (j) Maintenance (Gauge and Nearby Equipment)

6.2.2 Factors which should be considered by the gauge user and manufacturer in determining the need for additional evaluation or testing are:

- (a) Consequences of loss of activity.
- (b) Quantity of radioactive material contained in the gauge.
- (c) Radiotoxicity of the source material.
- (d) Chemical and physical form of the radioactive material.
- (e) Environment to which the gauge might be exposed.
- (f) Protection afforded by the sealed source capsule (ref. ANSI N542, Sealed Radioactive Sources, Classification).
- (g) Protection afforded the source by the gauge or source/gauge combination.

(h) Additional protection provided by auxiliary safety systems (i.e., crash barriers, shock mounts, fire protection systems, etc.)

(i) Effects of loss of shielding.

7. Testing Procedures for Table I

7.1 **General.** The testing procedures given in this section present acceptable procedures for determining performance classification numbers. All the criteria set are the minimum requirements. Procedures which can be demonstrated to be at least equivalent are also acceptable.

7.2 Use Condition Temperature Tests

7.2.1 **Test Equipment.** The device shall be tested in a temperature chamber capable of achieving and maintaining the minimum and maximum temperatures in the classification table when the device is operating with its normal heat load. Two chambers may be used, if necessary, to provide the temperature values. The device may be transferred, at room temperature, from the low temperature chamber following the low temperature portion of the cycle. Means shall be provided for monitoring the performance of the safety features of the device during the temperature test.

7.2.2 **Preparation.** The time required for temperature stabilization of the entire device at the temperature extremes shall be determined. The time may be determined experimentally or by calculation. Stray radiation from the device

shall be measured and recorded prior to beginning of the test.

7.2.3 Procedure. The device shall be placed in the chamber at room temperature and checked for proper operation of the safety features. The ambient air temperature shall be decreased to the low value shown in the classification table and shall be maintained at that value for the stabilization time plus one hour. After achieving stabilization the operation of the safety devices shall be verified and then again at 30 min and at the conclusion of this portion of the temperature cycle. The temperature shall be increased to room temperature and maintained for the stabilization time. At the conclusion of this portion of the cycle, the operation of the safety features shall again be verified.

The ambient air temperature shall be increased to the high value shown in the classification table and maintained at that value for the stabilization time plus one hour. After achieving stabilization the operation of the safety devices shall be verified and then again at 30 min and at the conclusion of this portion of the temperature cycle. The temperature shall be decreased to room temperature and maintained for the stabilization time. At the conclusion of this portion of the cycle operation of the safety features shall again be verified. The device shall be removed from the chamber and examined visually for defects. Stray radiation of the device shall be measured and recorded and the integrity of the source shall be verified.

7.2.4 Evaluation. During the temperature cycle there shall be no failure causing loss of function of the safety features. The visual examination shall reveal no defect which could result in loss of function of the safety features. Stray radiation at the conclusion of the temperature test shall not exceed the value recorded prior to the test. The sealed source capsule shall pass an appropriate leak test as described in ANSI N542. An x-ray tube source shall continue to operate within the original system radiation safety design specifications.

7.3 Stray Radiation

7.3.1 Equipment. For purposes of these tests when measuring beta or electromagnetic radia-

tion (gamma, x-ray, bremsstrahlung), the standard instrument shall be an air ionization chamber survey meter. The gamma and x-ray energy response of the standard meter shall be flat within ± 15 percent over an energy range of 15 keV to 1.3 MeV. Other meters may be used when they are corrected for response against the standard instrument for the radiation to be measured. The window thickness of the standard meter shall be no greater than 7 mg/cm². Additional absorbers may be required for gamma and x-ray measurements above 660 keV to obtain the corrected instrument energy response.

For purposes of these tests, when measuring neutron radiation, the standard instrument shall be a survey meter whose response in dose equivalent rate units (mrem/hour) is known over the energy range of .025 eV to 10 MeV. Window thickness requirements are not applicable to this type of instrument. The external absorbers specified in 7.3.2.1 shall not be used when measuring neutron radiation.

The survey meter used for these tests shall have been calibrated to the center of the probe's active volume not more than six months prior to the date of these tests. Beta-gamma survey meters shall be calibrated against a gamma radiation standard to an accuracy of ± 10 percent of full scale at a point within the rated energy range. Neutron survey meters shall be calibrated in dose equivalent rate units to an accuracy of ± 15 percent of full scale using a neutron source whose spectrum is within the instrument's rated energy range. (For calibration procedures, refer to American National Standard N323.) For additional discussion of survey meters, see appendix A.

7.3.2 Procedure. For measurement of stray radiation, the standard conditions shown in table II shall be established. If various isotopes and activities may be installed in a device, evaluations shall be made with each isotope and activity for which a device classification is desired. However, if classification has been established for the maximum activity of a particular isotope, this classification may be used for the device when incorporating lesser activities of the isotope. If a device incorporates more than one isotope simultaneously, tests shall be performed with all sources installed. If both neutron and gamma radiation fields are

present, each field shall be evaluated individually and summed to obtain the total dose rate.

In general, the isodistance contours for measuring stray radiation are at 5 cm, 30 cm, and 100 cm from the nearest accessible surfaces of the source and detector housings of the gauge. Measuring gaps of 10 cm or less are relatively inaccessible and whole body exposure to radiation within these gaps is improbable. Therefore, the 5 cm isodistance contours are not considered in this gap space. For measuring gaps greater than 10 cm, the 5 cm isodistance contours within the measuring gap must be considered under source OFF conditions. With the source in the ON condition the measuring gap space, defined by the surface dimensions of the housings, contains the useful beam and is excluded from consideration for defining the isodistance contours. The locations of the isodistance contours adjacent to the measuring gap are also simplified by making them parallel to imaginary surfaces between the source housing and the detector housing. These considerations are illustrated in figure I.

Figures IIA through IIF supplement table II and illustrate the isodistance contours and standard conditions to be used in determining the stray radiation classification of specific types of gauges.

7.3.2.1 Beta and Electromagnetic Radiation Measurement. The location of the maximum stray radiation shall be determined by scanning all accessible surfaces of the device with the survey meter at the distances specified in the classification table. After the general region of maximum radiation is located, a careful examination shall be made to determine the maximum radiation level. Care must be taken in all measurements to assure that the meter is oriented to obtain a maximum reading through the window and absorber, and that sufficient time is allowed for the meter reading to stabilize. Measurements shall be averaged over an area not less than 30 cm² and not more than 100 cm² with no linear dimension of this area to exceed 20 cm.

Distances shall be measured from the surface of the device to the center of the active volume of the survey meter. Dose rate measurements shall be made under two conditions

“dose rate (7 mg/cm²)” and “dose rate (300 mg/cm²)”. The first condition approximates what is commonly referred to as the dose rate to the “skin” of the body. The second condition applies to the dose rate to the “whole body, gonads, active blood-forming organs, head and trunk, or lens of the eye,” and assumes that the lenses of the eyes are not protected by any type of eye shields. For these measurements, an external absorber shall be placed over the window of the survey meter as necessary. For measurement of dose rate (7 mg/cm²), the total thickness of window and absorber shall be no greater than 7 mg/cm². For measurement of dose rate (300 mg/cm²), the total thickness of window and absorber shall be no greater than 300 mg/cm². For the external absorbers, a material such as polyethylene with a low effective atomic number (specific gravity approximately 1.0) shall be used.

7.3.2.2 Neutron Radiation Measurement.

The location of the maximum stray radiation shall be determined by scanning all accessible surfaces of the device with the survey meter at the distances specified in the classification table. Due to the large physical size of neutron survey meters, the measurement at 5 cm shall be eliminated. After the general region of maximum radiation is located, a careful examination shall be made to determine the maximum radiation level. Care must be taken in all measurements to assure that the meter is oriented to obtain a maximum reading and that sufficient time is allowed for the meter reading to stabilize. The measurement area is considered to be the cross-sectional area of the moderator. This cross-section shall include the largest dimension of the detector. For making radiation measurements, the cross-section which includes the largest dimension of the detector shall be placed normal to the incident radiation. Distances shall be measured from the surface of the device to the center of the active volume of the detector. Readings shall be interpreted as dose equivalent rates (dose rate (300 mg/cm²)).

7.3.3 Evaluation. All documents recording stray radiation measurements shall include identification of the survey meter and mass per unit area of absorbers used in making these measurements.

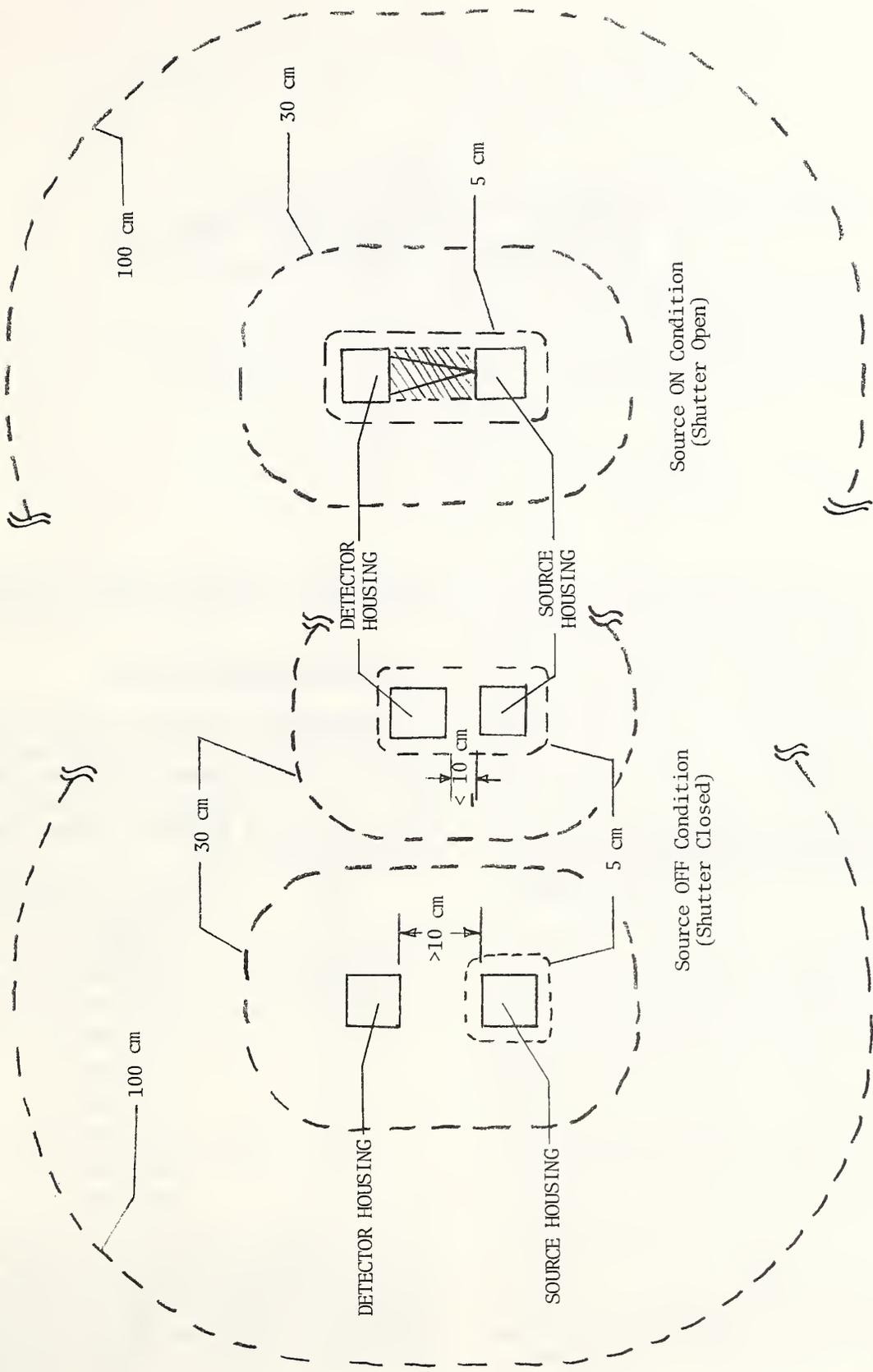


FIGURE I. Isodistance Contours

(Reference Section 7.3.2)

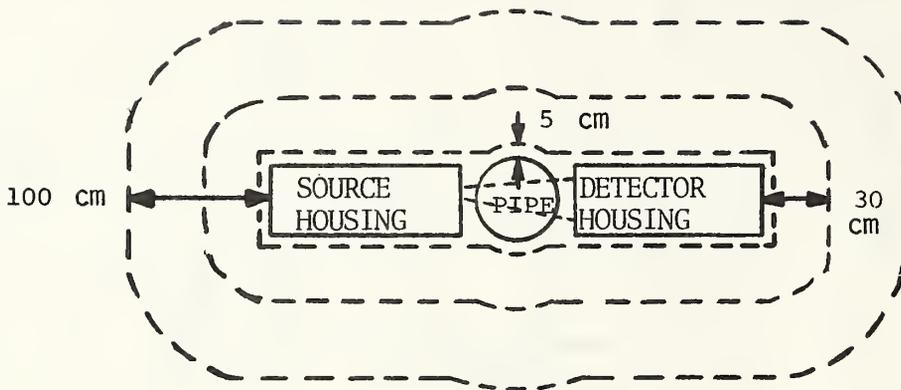


FIGURE IIA. *Density Gauge*

7.3.3.1 For devices emitting beta and electromagnetic radiation, the classification number for each distance shall be the number corresponding to the lowest radiation level in the classification table not exceeded by the maximum dose rate (300 mg/cm²) level measured for that distance. Dose rate (7 mg/cm²) shall not exceed six times the radiation level shown in the classification table. If the dose rate (7 mg/cm²) exceeds six times the value in the classification table determined by the dose rate (300 mg/cm²) value, divide the dose rate (7 mg/cm²) by six and classify by the resultant.

7.3.3.2 For devices emitting neutron radiation the classification number at 5 cm shall be 1. The classification numbers for 30 cm and 100 cm distances shall be the numbers corresponding to the lowest radiation levels in the classification table which are not exceeded by the maximum neutron radiation levels measured at those distances. If beta and gamma radiation are present, add the beta and gamma dose radiation values to the neutron dose rates (in mrem/h at each distance. The maximum total values shall be used for classification. When the dose rate (7 mg/cm²) value resulting from beta and electromagnetic radiation, added to neutron radiation, exceeds six times the value in the classification determined by the dose rate (300 mg/cm²) value, divide the dose rate (7

mg/cm²) by six and add this value to the neutron dose rate and classify by this resultant.

7.4 Accident Condition Fire Tests

7.4.1 **Equipment.** The furnace used for these tests shall have a thermal capacity adequate to heat the external surfaces of the gauge being tested to the test temperature in general accordance with the following standard time-temperature table:

TIME	TEMPERATURE °C
0	Ambient
5 min.	538 (1000 °F)
10 min.	704 (1300 °F)
20 min.	800 (1475 °F)
30 min.	843 (1550 °F)
1 h	927 (1700 °F)
2 h	1010 (1850 °F)
4 h	1093 (2000 °F)
8 h	1260 (2300 °F)

7.4.2 **Procedure.** All tests shall be performed in air. The temperature of the test device shall be determined by the average of readings of thermocouples disposed and distributed to show the temperature near all external parts of the

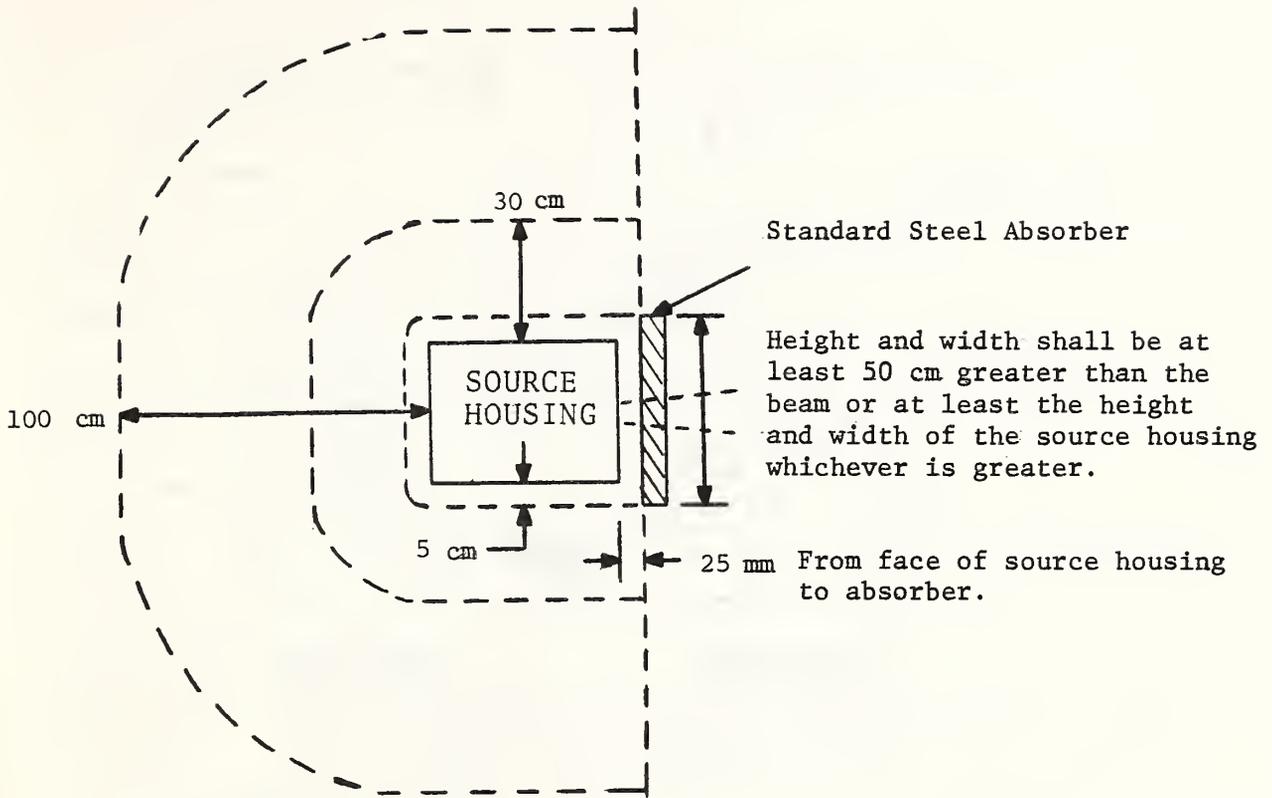


FIGURE IIB. *Level Gauge*

device. The fire endurance test shall be continued until the specified time-temperature conditions have been satisfied.

7.4.3 Evaluation. The test device shall be examined and tested for retention of the source in the source housing and possible leakage or dispersal of radioactive material from the device (reference section 6.1).

8. Quality Assurance and Control

To assure that production gauging devices will have performance characteristics equal to the tested prototypes used in classifying the devices, a good Quality Assurance and Control program is necessary. Appendix B is included as a guide to aid a manufacturer in establishing a specific program.

9. Revision of American National Standards Referred to in This Document

When the following American National Standards referred to in this document are superseded by a revision approved by the American National Standards Institute, the revision shall apply:

N323-1977, Radiation Protection Instrumentation Test and Calibration

N542-1977, Sealed Radioactive Sources, Classification

N543-1974, General Safety Standard for Installations Using non-Medical X-Ray and Sealed Gamma-Ray Sources, Energies Up to 10 MeV.

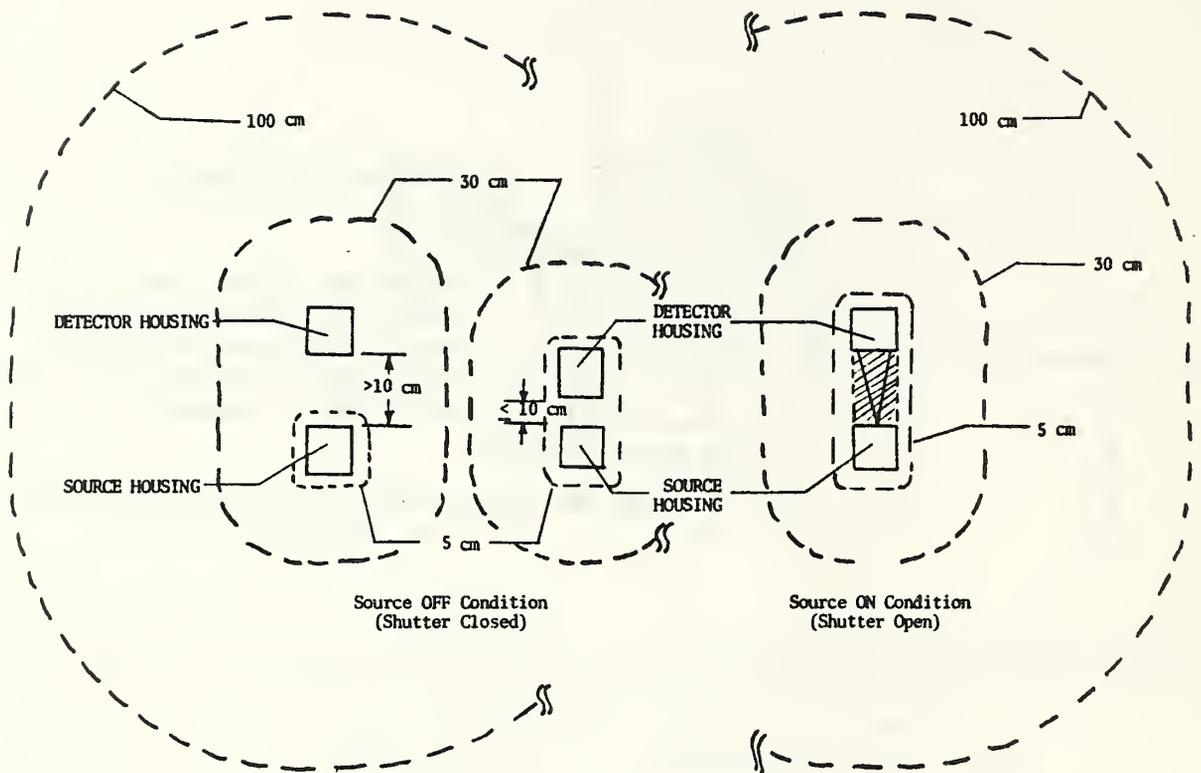


FIGURE IIC. *Transmission Type Gauge (Beta, Photon, Neutron)*

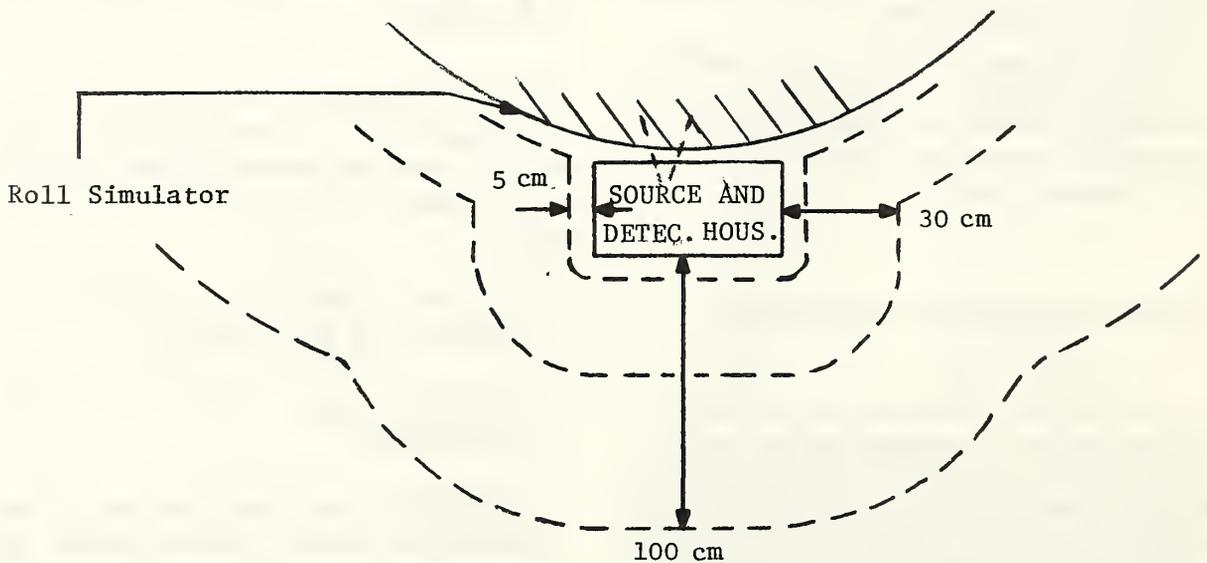
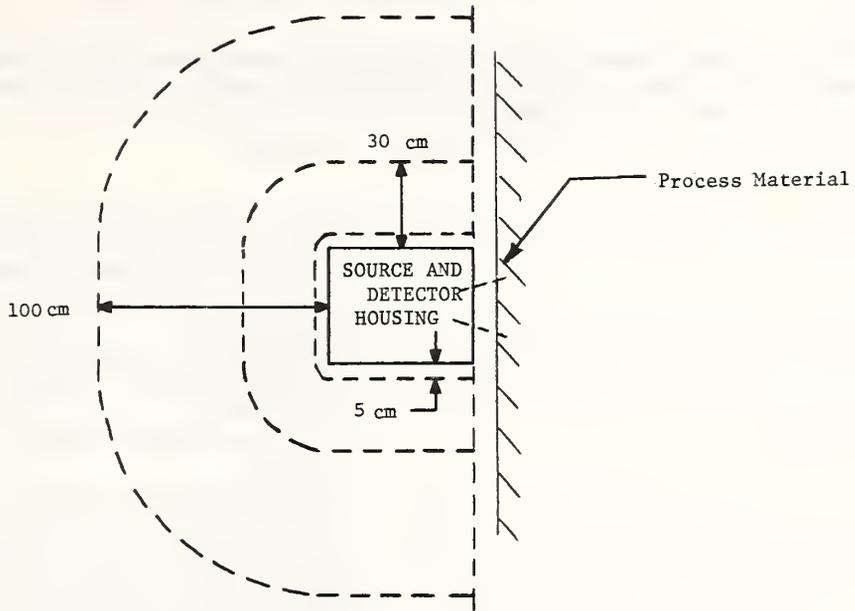


FIGURE IID. *Backscatter Type Gauge Utilizing Scattering-Backer (Beta, Photon)*



NOTE: Radiation shields or barriers may be required in the path of the useful beam beyond the process material. However, this is not considered in determining the stray radiation classification designation.

FIGURE IIE. Backscatter Type Gauge Utilizing Process Material For Scattering Surface

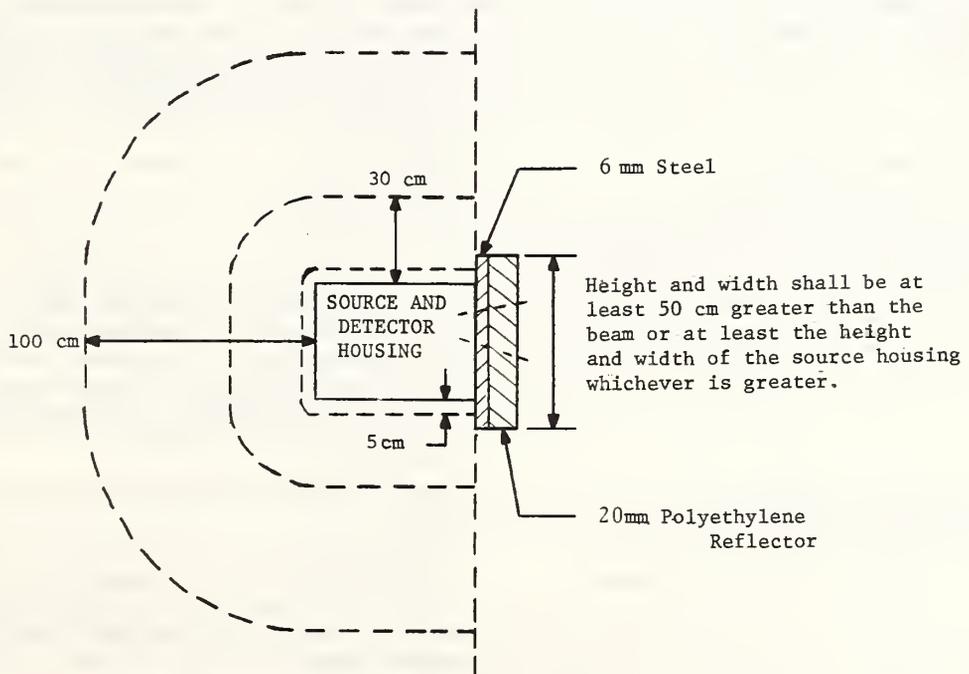


FIGURE IIF. Neutron Backscatter Gauge

TABLE II. *Standard Conditions for Stray Radiation Tests.*

GENERAL

In performing the stray radiation tests for any system, the gauge (source and detector housings) shall be mounted according to the manufacturer's installation instruction in a physical geometry which will be representative of the actual use condition.

SPECIFIC DEVICES

Density Gauge	<ul style="list-style-type: none"> — Gauge mounted on process or vessel (or simulation). — Test for all pipe sizes (or worst case). — Test with no process in pipe (empty). — See Figure IIA.
Level Gauge	<ul style="list-style-type: none"> — Source housing mounted 25 mm from a standard 13 mm thick absorber. (Vessel Wall Simulator) — See Figure IIB.
Belt Scale Gauge	<ul style="list-style-type: none"> — No belt or process in the measuring gap. (Empty Air Gap) — Test each measuring gap (or worst case). — See Figure IIC.
Photon Transmission Gauge	<ul style="list-style-type: none"> — No product in the measuring gap. (Empty Air Gap) — Test each measuring gap (or worst case). — For x-ray gauge, test worst case combination of operating kVp and mA available in gauge. — See Figure IIC.
Beta Transmission Gauge	<ul style="list-style-type: none"> — Same as Photon Transmission Gauge. — See Figure IIC.
Neutron Transmission Gauge	
A. Gauge Used on a Belt	— Same as Belt Scale Gauge.
B. Gauge used for a Product in a Pipe or Chute	— Same as Density Gauge.
Beta Backscatter Gauge	
A. Gauge used on a Roll or Other Infinite Backer	<ul style="list-style-type: none"> — Test for all roll diameters (or worst case). — Steel plate absorber (roll simulator), at the nominal measuring gap, of sufficient thickness to attenuate all of the useful beam beta particles. — No product on the Roll Simulator. — See Figure IID.
B. Gauge used on Product Not Supported or Backed up	<ul style="list-style-type: none"> — Typical product in the useful beam (or worst case). — See Figure IIE.
Photon Backscatter and Fluorescence Gauges	
A. Gauge used on a Roll or Other Backer	<ul style="list-style-type: none"> — Test for all roll diameters (or worst case). — For x-ray gauge, test worst case combination of operating kVp and mA available in gauge. — Steel plate absorber (roll simulator), at the nominal measuring gap, of sufficient thickness to attenuate 99 percent of the useful beam photons. — No product on the Roll Simulator. — See Figure IID.
B. Gauge used on Product Not Supported or Backed up	<ul style="list-style-type: none"> — Typical product in the useful beam (or worst case). — See Figure IIE.
Neutron Backscatter Gauge Used on Vessels	<ul style="list-style-type: none"> — Gauge housing mounted in contact with a standard absorber consisting of a 6 mm thick steel plate backed by a 20 mm thick polyethylene reflector plate. — No product in the measuring beam. — See Figure IIF.

Appendix A

Radiation Measurement

(This appendix is not a part of American National Standard N538, Classification of Industrial Ionizing Radiation Gauging Devices.)

The following are general guidelines for measuring stray radiation of gauging devices. They are recommended to provide uniformity in making these measurements and interpreting results. The specific procedure to be used in determining the stray radiation classification is described in section 7.3.

The stray radiation from a gauging device exists in the form of a spectrum of energies. Radiation to be measured generally consists of one or more of the following: beta, gamma, x-ray, bremsstrahlung, or neutron radiation. The energy range of interest is usually between 15 keV and 1 MeV. Scattering and secondary emission contribute to the lower energy components of stray radiation. The existence of a variety of types of radiation and energy levels requires the use of a survey meter with reasonably flat energy response. Air ionization chamber meters are available with an energy response within ± 15 percent from 15 keV to 1.3 MeV. These instruments may also be suitable for measurement at energy levels outside this range by applying appropriate correction factors. Air ionization chamber meters do not measure neutron radiation.

Geiger tube survey meters may be strongly energy dependent. This type of meter should not be used for stray radiation measurements unless the meter has been corrected for response against the standard instrument for the radiation to be measured. Geiger tube survey meters are useful for preliminary scanning to locate any small voids in the shielding. Pin-hole defects are less likely to be detected by ionization survey meters. Scintillation counters are not usually suitable for quantitative stray radiation measurements.

Beta particles are emitted with a continuous energy spectrum ranging from zero to a maximum value for the particular emitter. Dose response characteristics of any portable survey instruments for beta radiation are strongly energy dependent. As a consequence, survey instruments are generally used only to detect beta radiation but not to measure dose rate and are, therefore, not normally calibrated for beta dose rate measurements. Air ionization chamber instruments most nearly measure beta dose rates with reasonable accuracy. For this reason this type of instrument has been selected as the standard meter for this classification standard.

When pure beta emitting sources are used in gauging devices, the scattered radiation will be predominately beta while the remaining stray radiation may be bremsstrahlung. Some beta sources also emit gamma rays.

Survey meters are available with a variety of window thicknesses. For measurement of "skin" dose rates a window thickness not exceeding 7 milligrams per square centimeter is required because an individual has a protective layer of dead tissue of approximately 7 milligrams per square centimeter.

For measurement of "whole body (including lens of the eye, gonads, and active blood-forming organs)" dose rates a window thickness not exceeding 300 milligrams per square centimeter is required because the lens of the eye is located at a depth of 300 milligrams per square centimeter. The required thickness may be achieved by adding external absorbers over the window of the survey meter. Survey meters which will accept both absorbers are readily available.

When selecting a survey meter for measuring a particular type of radiation, the response of the meter to other types of radiation must be known so appropriate corrections can be applied. Items to be considered are: the sensitivity of the survey meter to R. F. radiation, micro-waves, neutrons in an ionizing electromagnetic radiation field, and gamma or x-ray radiation in a neutron field.

Appendix B

Quality Assurance and Control

(This appendix is not part of American National Standard N538, Classification of Industrial Ionizing Radiation Gauging Devices.)

B1. Introduction

All gauging devices within the scope of this standard should have associated with their manufacture a documented quality program, possessing, as a minimum, the attributes stated in this appendix.

The authority and responsibilities of the organizational unit or individuals performing the Quality function should be stated clearly in writing.

B2. Authority

Persons performing the Quality function should have the authority to:

- (1) Examine all records of the gauge program which are relevant to radiation safety.
- (2) Reject and obtain proper disposition of defective material and workmanship.

B3. Responsibilities

Persons performing the Quality function should be responsible for:

(1) Participating in design review of the gauge, identifying and suggesting necessary improvement in the gauge components which constitute or satisfy the safety features and requirements of section 3 of this standard.

(2) Monitoring the performance of, and record keeping associated with, prototype testing, and verifying that gauge production models meet the stated radiation numerical classification.

(3) Devising and implementing documented test, inspection, and corrective action procedures for gauge components which constitute or satisfy the safety features and requirements of section 3 of this standard.

(4) Establishment of an audit procedure, monitoring all aspects of the gauge program which may affect radiation safety such as installation, servicing, shipping and instruction manuals.

B4. References

The gauge manufacturer may also find the information in the following documents useful:

ANSI Z 1.1 GUIDE FOR QUALITY CONTROL

ANSI Z 1.8 A QUALITY PROGRAM, GENERAL REQUIREMENTS FOR

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS Handbook 129	2. Gov't. Accession No.	3. Recipient's Accession No.
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16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.) This American National Standard applies to the radiation safety aspects of gauging devices, commonly called gauges, which use sealed radioactive sources or x-ray tubes for the determination or control of thickness, density, level, interface location, or qualitative or quantitative chemical composition. This standard establishes a system for classification of gauging devices based on performance specifications relating to radiation safety. In addition to specific tests for both use conditions and accident conditions, guidelines for other safety features and considerations are presented. This standard does not apply to the measurement performance of gauging devices.		13. Type of Report & Period Covered Final	
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